Verification Loads Analysis Requirements and Approaches

SSP Payload Structures TIM

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Purpose of the VLA

- To provide personnel safety, Space Shuttle integrity, and efficient use of flight and ground systems by all users, payloads requirements have been established for verifying payload-to-Orbiter structural interfaces
- The objectives of the structural interface verification program are to verify that the payload structural hardware is compatible with the Space Shuttle.
- Prior to flight on the Space Shuttle, all payload structures will be demonstrated safe for flight and meeting all requirements for structures and safety.
- The Integration Plan (either Mission or Payload) is the contractual document that begins the loads analysis process. (NSTS 07700 Appendix 4)
- The VLA is the final official cargo system coupled dynamic and quasi-static structural analysis that is conducted prior to launch.
  - The VLA is the final structural mission risk assessment tool.
- A mission-specific VLA is performed for the SSP-specified Orbiter cargo bay manifest.
  - Any manifest variations are to be documented in the MI/PIP and will require a VLA (LON, alternate configurations, etc)
    - STS-121 with ICC and ESP-2

Parts of the VLA

• DESIGN LOADS ANALYSIS	L-13 months
• SSP Compatibility Assessment	L-12 to 9 months
• PVLR	L-10 months
• MATH MODEL DELIVERY	L-7.5 months
• VADAR	L-7.0 months
• DATA DUMP	L-5.5 months
• VLA REPORT PART 1	L-4.5 months
• VAR	L-3.5 months
• COFR SUPPORT/FRR	L-2 to 1 months
• VLA REPORT PART 2	L-1 month

CE Developer Design Loads Analysis (L-13 M)

- Cargo Element (CE) developer is responsible for the validity of the DLA data
- QS flight events typically result in minimum Orbiter-to-CE clearances and must be performed as part of the CE DLA effort
- CE can be placed in and analyzed in multiple cargo bay location if the final position in the cargo bay is not known or the CE can fly in multiple locations
- Should include SWG concurred to model uncertainty factor
  - Typical numbers are 1.5 for PDR level, 1.25 for CDR level, and 1.1 for post-CDR models that are verified and being used to support DLA's prior to the VLA
- DLA should include deflection calculations between the CE and Orbiter for the following:
  - CE structures within 3 inches of 90-inch radius envelope
  - CE structures outside 90-inch radius envelope
  - CE structures within 3 inches of Orbiter protuberances
- Report delivery schedule documented in the MIP or PIP
- Contents of report defined in App. D of NSTS 37329 (updated)

SSP Compatibility Assessment

- Performed for every flight
- Compatibility Assessment supports the Cargo Compatibility Review (CCR) at L-11 months and the Cargo Integration Review (CIR) at L-9 months.
- Uses CE Developer delivered Design Coupled Loads Analysis (DCLA) data
  - Assesses interface loads and deflections for compatibility for the flight
    - Deflections of 3” are assumed when the DCLA data does not include that information
  - VLA used to verify the resolution is acceptable for the specific mission being analyzed
    - VLA only verifies dynamic clearance losses – static clearances verified by measurement
  - Identifies items requiring Section 20’s (WDE) in their ICD due to clearance concerns or envelope violations

PVLR (L-10 M)

- Purpose
  - Ensure that all CE structural math models and verification analysis data output requirements are provided to NASA/JSC and BNS to start the VLA process
  - Define contingency landing cases so that models can be developed
- Presentations
  - By Boeing, reviewing the SSV math models to be used, the VLA plan including forcing functions and cases to be considered (liftoff, landing, contingency landing, etc), Section 20 items (clearances) to be monitored in the VLA and points to be retained by the CE developer in the models, on-orbit review, failed open vent analysis and payload venting (to be considered by the CE structural analyst in their assessments), and data transfer FTP site
  - By CE developer, per outline in Appendix H of NSTS 37329, including an introduction to the CE, the math model verification, math model description including format, close clearance points, unique analysis requirements and data requirements
    - Unique analysis requirements may need to be identified prior to PVLR to allow the schedule to be modified if necessary to accommodate (see NSTS 37329 section 3.3)
  - By SWG, outlining the currently defined model uncertainty factors on each of the CE's, and also any data missing to define that UF.

Math Model Delivery (L-7.5 M)

- Math Models delivered to Santha Susarla / Boeing-NS via FTP or other method discussed at PVLR
- Math models developed in standard format defined in NSTS 37329 app. I or other format pre-approved by SWG and USA/Boeing
  - USA/Boeing verifies the format is compatible with the current set-up
    - Providing models in a format other than the standard or pre-approved format may delay the VLA
- All information to be delivered at same time
  - Use of PMSF to help standardize data delivery and speed check-out process
    - Separate presentation on PMSF to be given
  - Includes thermal and manufacturing tolerances, misalignment loads, all math model checks
  - Models to be provided in double precision

VADAR, Data Dump, Report Part 1

- Purpose of VADAR (L-7 M)
  - Verify that the CE models that Boeing has received are correct
  - Verify that the output requested from Boeing is correct and complete
  - Verify that the requested output will be going to the appropriate folks
  - Verify cases that are to be analyzed
  - Verify any UF's to be included in the assessment
  - Verify the SWG has reviewed and approved all models to be used in the VLA (SWG letter)
  - Verify method of providing data dump to CE developers – either Boeing FTP or CE developer identified site (to be tested prior to data dump)
  - Give Boeing the go-ahead to start the VLA
- Data dump – is exactly what it says (L-5.5 M)
  - Data placed on Boeing FTP site – CE developers access with user name and password
- VLA Report part 1 (L-4.5 M)
  - Electronic report with VADAR charts and VLA data output

VAR and Report part 2

- Purpose of VAR (L-3.5 months)
  - Review compatibility of the payload manifest with the flight environment
  - Boeing presents Orbiter compatibility and clearance assessments (rationales for section 20's)
  - CE presents margins for their structures
    - Can be comparison with design loads showing VLA is enveloped
    - For additional cycles, can be comparison with first cycle showing enveloping, identifying only those items not enveloped and requiring additional analysis
    - Topics to be presented at the VAR are documented in NSTS 37329 Appendix J
- VLA Report Part 2 (L-1 month)
  - All VAR/FAR charts including clearance results and resolution of any mass property issues (out of tolerance)

SSP Developed Load Indicator Approach

- Within the standard VLA process
  - Orbiter and CE's are responsible to verify the VLA results with a Manifest Uncertainty Factor (MUF) applied above any SWG specified UF
  - B-NS creates database of max/min values for each OTM item
- A planned or unplanned two part VLA effort
  - Addresses known late test-verified model deliveries
  - Addresses late manifest changes which require another VLA to be performed
  - Accommodates errors in submitted math models or violations of the weight and cg tolerances

  GOAL IS NOT TO HAVE TO CONDUCT ADDITIONAL VLA's
- Off-nominal Activities
  - No MUF would be applied, in most cases, to additional VLA cycles
    - SWG identified criteria, when met, may eliminate the need to perform an additional VLA
    - Any model or OTM updates shall be in the same format and sequence with additional items placed in a new OTM
  - As part of the additional VLA effort, each CE will receive, in addition to the requested output, a comparison table of the new VLA max/min results to the first cycle. Each CE will be responsible to verify their hardware and report results at the Final Acceptance Review (FAR) (VAR for additional cycles).

Weight and C.G. On-going Validation

- NSTS 37329 requires the across-the-bay payload math model to be within +/- 200 lbs. of the as-weighed hardware and the center of gravity (CG) to be within 1” RSS of the measured CG
  - SSP/USA and the SWG will determine whether an additional VLA or sensitivity studies will need to be run if the mass properties updates cause the model to be outside the generic tolerances mentioned above
  - Coordination with SWG can begin even prior to VLA if the weight is dynamic in nature or if there is uncertainty in the final weight
- Mass properties should be continually monitored by the VLA math model developers
  - Keep copy of original model submitted for VLA and keep one copy of the VLA model which is continually updated with the mass properties as they are updated/available
  - Make checks between the two models (frequencies, modal effective masses, cross-orthogonalities) when the above tolerances are exceeded
  - Provide results of checks to the SWG for review
  - Final weighing/CG measurement of payload is NOT the time to be making major mass property adjustments to the model

Structures Home Page

- Bookmark this page!

  http://sspweb.jsc.nasa.gov/webdata/mshome/struct/st-index.htm

- This page contains links to:
  - Most commonly used and up-to-date Structures documents (for example, NSTS 14046 and 37329)
  - Proposed changes to NSTS 37329 will be posted for review
  - Will contain additional information prior to being incorporated into NSTS documents (interpretation letters)
  - Current and past flight activity (in VLA template)
    - By flight number
    - Includes manifest
    - VLA schedule (need to turn on macros for this to open properly)
    - Posting of charts and notification letters
  - Address information for the SSP and Structures community is sorely out of date!
  - Master Action Item tracking list for VLA meetings

Requirements often overlooked

- Test verified math models need to meet the L-7.5 months delivery date
  - This is not a “suggested” date – it is an SSP Program Requirement
  - Test verified means that the SWG has reviewed the model and approved, not just received the information on the test verification
- All math model checks need to be delivered with the models
  - PMSF will help with this issue
- OTMs provided for additional cycles need to match up with original delivery
  - Reason: Having identically sized OTMs makes it possible for Boeing NASA-Systems to complete comparison tables and reduces comparison errors
  - Solution: For second and subsequent cycles, submit original OTMs with zero’s for DOFs no longer required and any additional OTM items to be supplied in another OTM

New Requirements

- OTM with minimum items needs to be supplied with model for sanity check
  - Orbiter attach locations non-tied DOFs to be included (new requirement in 37329, App I, item 4.4)
- Other new requirements to be addressed in the NSTS 37329 presentation

Miscellaneous

- Instant meeting used for VLA teleconference meetings – please state your name slowly and clearly when prompted – it lets Don and myself know who joins so we don't have to stop and ask who just joined.
  - Will do a roll call on all telecons since folks not sending in attendee lists. If you join late, please be sure before the telecon ends, that you let us know you were in the meeting.
- Meeting minutes are used to close action items and document agreements in meetings. If you present during a VLA meeting, please review your section for accuracy. These minutes are referenced later on for different issues. If you don't verify the accuracy of any of your statements, it will go in the formal record incorrectly.
- I am not the SWG person, I cannot speak for the SWG. Tony Ng/Lockheed Martin has presented contact information for the SWG.
  - The SWG verifies that the payload has completed its verification requirements, follows the VLA verifying that the payloads assess the VLA data, and helping with additional issues such as weight and cg tolerance exceedances.

Conclusions

- The VLA is the final risk assessment for the Space Shuttle Program that the Orbiter and cargo elements are compatible.
- The VLA schedule is not changing and the template was shown.
- The Load Indicator Approach used for planned and unplanned additional cycles was reviewed.
- Reminder to all CE developers to monitor the final weight and center of gravity of the CE.
- Reminder to all parties of the often overlooked requirements such as OTM items.